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FIELD TEST OF LIFEJACKET FLOTATION MATERIALS.(U)
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U.S. Department
of Transportation
United States
Coast Guard

Field Test of Lifejacket Flotation Materials

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and
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Office of Merchant
Marine Safety
Washington, D.C. 20593

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Final Report

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All laboratory testing referred to in this report was conducted by the Marine Department of Underwriter's Laboratories in Tampa, FL.

16. Abstract

This report represents the results and analysis of a field test program for personal flotation device (PFD) flotation materials. The field test was conducted at several boat and canoe liveries throughout the Eastern United States. The test was intended to determine if significant losses of buoyancy occur among various flotation materials when subjected to "field use" environments and if so, to determine if the deteriorization process can be simulated in laboratory environment.

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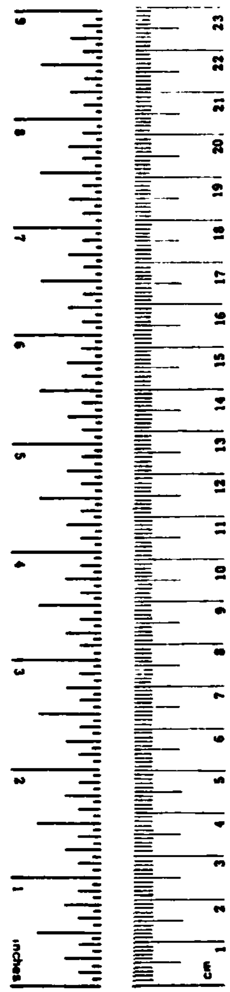
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

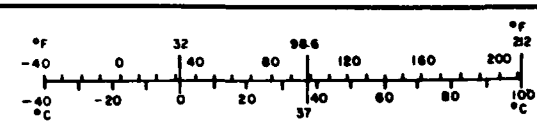
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

We would like to thank all those foam manufacturers and livery operators who assisted in the field test program. It should also be noted that all laboratory testing was conducted at UL and for these reasons much of the technical information and data is taken from the UL reports of the program to the Coast Guard. UL also provided a great deal of valuable analysis and input into our analysis, assumptions and conclusions. For this we would like to thank the members of the Marine Department of Underwriters Laboratories.

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1. INTRODUCTION

This report discusses a field test of flotation materials which are used in U.S. Coast Guard approved personal flotation devices (hereafter referred to as PFDs). The flotation materials are of two basic types; kapok, a fibrous material which comes from the silky fibers that clothe the seeds of the ceiba tree, and unicellular plastic foam such as expanded polyvinylchloride or polyethelene foams (hereafter referred to as PVC or PE foams respectively). The study was initiated as the result of research showing significant buoyancy losses with PFDs under normal use and other field experience showing problems with the buoyancy of approved PFDs after only a relatively short use, the most significant of which occurred in 1980. It was determined that the failing PFDs were losing buoyancy at an unacceptable rate. Since PFDs are U.S. Coast Guard approved, and part of the approval process involves approving the components which make up the PFD, the Coast Guard was obligated to conduct tests to determine what was causing the loss of buoyancy.

Up until this time, PFD components were tested either to a Coast Guard component specification subpart, a Military Specification (MIL-SPEC) as specified in the regulatory subpart for the PFD, or an Underwriters Laboratories (hereafter refered to as UL) Standard. Unlike the Coast Guard and Military specifications, specific requirements for buoyant materials were not specified in UL Standard 1191. Instead, a class loss rating was assigned for buoyant material tested under UL 1191. It was assumed that the marketplace would weed out the materials which required too much supplemental buoyant material to correct for potential losses. This was proving not to be the case. Therefore, in conjunction with UL and manufacturers of UL recognized materials, the Coast Guard started this project to determine what materials can be expected to provide adequate service life and to see if a more realistic laboratory testing procedure or standard could be found.

2. OBJECTIVES

The field test program was designed to determine the difference in buoyancy loss for all types/brands of buoyant material when subjected to the same usage. This was the basic objective of the testing program. However, there were also additional questions which hopefully would be answered by the test program. These supplemental objectives were:

(a) To provide a basis on which an acceptable revised performance standard could be developed.

(b) To determine whether or not the field conditions could be simulated under laboratory accelerated aging conditions, and if so, what types of tests could be used to simulate the field conditions.

(c) To determine causes for the buoyancy losses which were appearing in USCG approved PFDs, even though the PFD was used only for a short period of time.

(d) To determine if the characteristics of materials which were experiencing high buoyancy loss could be isolated.

(e) To determine if any specific pattern or loss rate could be developed which could be used to predict long term and future buoyancy losses.

It was anticipated that by obtaining the answers to these questions, a complete revision could be made to the foam requirements of UL 1191, thereby making it an acceptable alternative standard for the Coast Guard to use in accepting buoyant materials as equivalents to the CG specifications.

3. DISCUSSION OF FIELD TEST

3.1 Field Test Overview

Since the most severe buoyancy complaints dealt with foam buoyant materials used in Type IV PFDs (Flotation Cushions), the field test plan was to submit sample cushions made of the full range of PVC and PE foams and kapok to liveries which use these devices quite hard. Control samples of all the materials were also maintained. Since the industry believed that the usage of vests might be significantly different from Type IV cushions, some of the flotation material manufacturers also wanted to include vest type PFDs in the field test. This proposal was accepted provided that any material which was to be tested in a vest was also tested in sample cushions. The scope of the test included a cross section of all PVC and PE foams which were being used in USCG approved PFDs of all types. This approach to the problem is documented in a coordinated test plan which was accepted by all of the participants in the program. A copy of the coordinated test plan is included as Appendix A.

3.2 Participants

There were four groups involved with the field test. These groups were the U.S. Coast Guard, Underwriters Laboratories, Flotation Foam Manufacturers, and Test site personnel. The Office of Merchant Marine Safety, Merchant Marine Technical Division, Survival Systems Branch was the section of the Coast Guard responsible for the test. The Marine Department was the section of Underwriters Laboratories involved in the the test. Ten flotation foam manufacturers took part in the field test. These manufacturers are listed in Appendix B. The test sites consisted of various types of recreational boating liveries. These liveries are listed in Appendix C.

3.3 Sample Preparation

In order for the test to show differences in flotation material only, a rigorous systematic method of placing it into service had to be devised. It was decided that the most meaningful way of placing the material into the test environment was to take the flotation material supplied by the manufacturers and use the samples as inserts in Type IV PFDs (cushions). These cushions would be specially prepared by a single PFD manufacturer chosen by the Coast Guard. Only one PFD manufacturer was chosen to make the sample cushions to ensure sample uniformity. The PFD manufacturer selected to make the sample cushions was Ero Industries in Hazlehurst, Georgia. The cushions were made under the direct supervision of representatives of the Coast Guard and UL.

There were two manufacturing sites for the vests, Ero Industries in Hazlehurst, Georgia, and Stearns Manufacturing in St. Cloud, Minnesota. It was the responsibility of the flotation foam manufacturer to ensure proper construction of the sample vests.

The flotation material manufacturers were requested to submit enough material to provide the following:

(1) 3 Square yards for identification and UL 1191 tests.

(2) 10 samples, each 16 X 9 X 1 inches for the accelerated aging tests.

(3) Enough material to make 22 sample cushions 15 X 15 X 2-1/2 inches.

(4) Enough material to make the sample vests, if vests were to be included in the study.

The materials for (1) and (2) were systematically taken from the same sheets of material as the sample cushions (3) were made. A detailed description of the fabrication process is given in Appendix D.

As the sample cushions were made, each was marked with a code number that could be used to identify the buoyant material inside. This code number consisted of two parts, a manufacturer's code and a consecutive sample number. The manufacturer's code indicated two things, the source of the buoyant material and the type of material it was. Therefore, each manufacturer could have more than one code. Each manufacturer would have as many codes as the number of different buoyant materials or material thicknesses they provided. For example, in the code number 20-14, the number 20 would indicate which manufacturer had supplied the buoyant

material and what type and thickness it was, the number 14 would indicate the 14th cushion made with that particular material. This system of coding could allow us to trace any sample back to its source.

The vest samples were marked in a similar manner. However, since the vests were being made in more than one location, some errors were made in marking which allowed duplicate numbers to be assigned. This obviously caused some problems in analyzing the vest data as is explained in reference (a). Reference (a) is the report of the meeting between the Coast Guard, UL, and foam manufacturers, which took place on the 15th of December, 1981, at U.S. Coast Guard Headquarters, Washington, DC.

As indicated in Appendix D, the covers for the sample cushions were pre-manufactured to the specified size. This created a problem for some of the foams which were manufactured on the high end of the thickness tolerance. The cushions were designed to allow sufficient layers of the foam to achieve the regulatory minimum buoyancy of 18 pounds. Some of the thicker foams could not fit enough layers into the pre-manufactured covers to achieve the 18 pound requirement, thus making some cushions underbuoyant.

3.4 Sample Distribution

After all of the samples had been made, they were sent to UL where they were tested to determine their buoyancy at the start of the test program. Some of the samples were also weighed at this time. The testing procedure used by UL is included as Appendix E. The initial buoyancy testing was completed on May 21, 1981. At this time all cushions with buoyancies of at least 16.5 pounds were authorized to be distributed to the liveries. In the interest of safety, the other cushions were not sent out with these samples. A table showing where each sample was shipped to is included as Appendix F. The cushions with less than 16.5 pounds of buoyancy were sent to Disney World and Cypress Gardens. These two Florida recreational parks were selected to receive these cushions because of the more controlled environment in which the cushions would be used.

Each livery was asked how many devices they could keep in continuous use and then only given enough devices to ensure that the test devices would be subjected to relatively continuous service. This rotational type usage system was intended to establish uniform usage of each test device without requiring records for each use. The system of rotational usage was set up by each livery.

A reference sample was sent to Coast Guard Headquarters to be maintained in an air conditioned room and another reference sample was maintained on the roof at UL, in Tampa, to subject it to a continuous outdoor exposure. Results for these reference samples are given in section 5.1.

3.5 Laboratory Testing

While the liveries were using the sample devices, UL was to conduct identification and accelerated aging tests on the various foam types and thicknesses. The identification tests were to be conducted on five material specimens which were taken from various locations within each lot of material as described earlier. These tests were to identify all the sample materials by their density, buoyancy (displacement for kapok), compression set, compression resistance, cell size, and bulk processed buoyancy for kapok. The material buoyancy was to be tested by the displacement method and was to be tested twice by two different technicians to eliminate some of the human error.

After identification of the materials, UL was to start conducting accelerated aging tests. These tests were to provide data so a valid laboratory testing sequence could be included in a revision to UL 1191. The samples were to be made up from rectangular pieces of foam skived down or plied up to achieve 1" thichness. Five of these samples of foam made a sample set. Two sample sets of each foam included in the program were to be tested. The initial accelerated aging simulation tests which were planned, are shown in Appendix A.

Due to several factors, including the inital results of the accelerated aging tests and the early cushion sample returns (which will be discussed in section 3.6), the laboratory test portion of the field test study was redirected several times. For this reason the accelerated aging simulation and the revision of UL 1191 has not yet been completed. A detailed description of the changes and the work completed to date is contained in the three progress reports by UL of the field test program (References b, c, and d). UL is continuing to work on this problem.

3.6 Early Sample Returns

On the 28th of July 1981 eleven sample cushions were returned to UL. After only one and a half months of use these cushions showed a large volume loss (apparently due to crushing) and water retention. UL conducted buoyancy tests on these cushions and found significant buoyancy losses (as high as 67%). This caused a major shift in the laboratory testing. The initial theory for buoyancy losses in flotation foams was aging due to weathering (sun, spray, heat, compression, etc.). Now a new scenario seemed likely. The eleven sample cushions were made of multi-layered PVC material. These samples which were returned from the field suggested that water absorption and then shear and crushing forces caused the foam cells to break allowing even more water to be absorbed into the foam. Possible failure modes will be discussed further in sections 4 and 5.

3.7 End of Field Test Data

During September, 1981 the field test sample cushions and vests were returned to UL. In addition to returning the sample devices, the liveries were asked to fill out a questionnaire on the use of the devices. The responses on the questionnaire are approximations or best estimates of the liveries as to how the test devices were used. Upon receipt of the sample devices, UL again tested them for buoyancy using the same method contained in Appendix E. Also, the samples which were weighed at the beginning of the field test were weighed again. With the aid of a computer, calculations were then made to determine the buoyancy losses of the devices and a tabulation of the results was performed. A summarized version of the cushion data from the seven most severe use liveries is included as Appendix G. A complete data tabulation is contained in reference (a).

ASSUMPTIONS

4.1 Initial Program Assumptions

Several assumptions were made during the planning stage of the field test program. Some of these assumptions were later proven incorrect, others were partially correct and some were shown correct. At the planning stage these assumptions were only made to limit the scope of the test program when the cost would be too prohibitive to do otherwise.

The first assumption was that there would be no significant difference in buoyancy loss rates between vests and cushions. This assumption was opposed by several manufacturers. They believed that vests would not lose as much buoyancy because the use and loading of a vest was different than the cushions. Whereas the Coast Guard believed that generally, cushions were probably used harder than vests, it was believed that some vests would receive usage just as severe as cushions. The disagreement on the losses of the vests as compared to the cushions led to the inclusion of vests in the study.

For the sake of laboratory testing, the cause of the buoyancy loss was assumed to be due to weathering or aging and wear and compression of the PFD. It was believed that the aging was the result of exposure to ultraviolet radiation, spray, and heat. These assumptions led to the initial laboratory accelerated aging tests.

No assumptions were made about the durability of the various materials as PE, PVC and kapok were all included in the study. Even though it was expected that similar performance would occur within the families of PE and PVC foams, no foam materials were excluded from the study based on this expectation.

It was also assumed that the results of the buoyancy test would be repeatable. In other words, the buoyancy obtained at the beginning of the program could be compared directly to the buoyancy obtained at the end of the program and any difference could be declared buoyancy lost over the period of the program. However some verification testing was included to check this assumption.

After analyzing the early sample returns, the assumption concerning the cause of the buoyancy loss was changed. The samples which were returned early indicated a large amount of water absorption. They also exhibited severe cell deterioration according to UL. This led to the assumption that the buoyancy losses were due to water absorption and subsequent cell wall rupture upon compression which caused more water absorption. This assumption caused UL to make a change in the type of accelerated aging which they were performing. Accelerated aging simulations have not been completed at the time of this reporting to determin- if this assumption is valid.

4.2 Assumptions Made in Final Analysis

As with any test data, there was some variation in the data due to uncontrolled variables in the use and testing. Therefore, some assumptions had to be made based on the trend of the majority of the results. These assumptions, which are explained in the following paragraphs, are believed to be logical and valid extrapolations which were derived from joint (UL and CG) analysis of the data. These assumptions were also presented to the participating foam manufacturers during the 15th of December 1981 meeting and no major objections were raised.

In order to establish a workable standard from the data, some assumptions had to be made dealing with the "real world" uses of the buoyant materials. The first of these assumptions was to establish a set period of time for the serviceable life of the PFDs in which the materials are used. Based on experience with "real world" usage of PFDs, it is assumed that the life expectancy of a PFD is approximately 3 years when used as hard as the test devices were. A case could be made for a longer service life.

The field test showed that the loss rates for vests and cushions are different. Therefore, in order to assign a loss rate to a material the use must be determined. However, in the interest of providing more flexibility in testing and getting full use of the data for materials which were tested in cushions, a relationship between vest losses and cushion losses was desired. An evaluation of the data led to the assumption that the two loss rates are related. The relationships will be explained in section 5.

One of the last problems encountered in the analysis of the buoyancy losses was the assignment of a curve of best fit to the graphs of buoyancy loss with respect to time and buoyancy loss with respect to the thickness of the material. Based on data from PFDs collected from actual use and data reported in a 1978 research report, titled "Personal Flotation Devices Research - Phase II" (reference (e)), it is now assumed that the buoyancy loss rate with respect to time is linear. Based on some laboratory aging tests also reported in that study, this assumption is believed to be conservative, but not overly so in light of the useful life assumption made earlier. The rate of loss may slow after several years but it does not stop.

The buoyancy loss rate with respect to thickness of the material (especially PVC) is not linear. It is, however, assumed that a characteristic curve can be assigned for each material and that curve can

be used to interpolate the loss ratings for intermediate thicknesses. The number of data points necessary to fit a curve with reasonable accuracy is greater as the materials get thinner.

5. ANALYSIS OF DATA

5.1 General

The data on the final buoyancies of the field test devices was analyzed to determine (1) if any of the devices would not have acceptable durability in actual use and (2) if any revisions should be made in how materials are incorporated into devices to have acceptable durability. Additionally, (3) the data was organized to provide a usable data base for developing a revised standard and (4) some analysis was done to predict long term or life time buoyancy losses.

With losses approaching 50%, (see Figure 1) the first and most obvious result is that the cushions were in a type of actual service which made some of the constructions unserviceable in less than one season. It should be noted however, that the devices which performed most poorly were made differently than any approved device in that multiple layers of thin gauge PVC material were used without bonding the layers together. Multiple layers of PE is, on the other hand, a common construction which has been approved and used. The results from the tests of the thin guage PVC materials is still of value in analyzing durability in other applications.

The average buoyancy loss for all samples used in the final analysis was 9.4% loss. The samples stored in an air conditioned space had an average gain in buoyancy of 1.1% while the samples exposed on the roof at UL had a 1.3% loss. The gain in buoyancy is attributed to recovery of compression set received during shipment, handling, and storage of the bulk materials to the manufacturer and of the large cartons of new cushions to UL for initial testing. The loss from roof top exposure is probably due to heat aging and perhaps a small amount of UV degradation. It is apparent that for the samples put into field service the losses are due primarily to usage and to a limited extent due to aging.

5.2 Cushion Usage

It became apparent when studying the data that for any given material there were large differences in the amount of buoyancy loss for the individual sample cushions depending on where they were used. Also, that some of the use locations resulted in significantly less severe "use" as reflected in no measurable buoyancy loss. Statistical analysis via pair-wise comparison shows this to be true. Since some of the use locations were not showing significant changes in buoyancy they were not contributing to the study. And since the pair-wise comparison showed it to be a function of the use location, only the ten cushions of each sample set which were in service at the seven most severe use locations were used in analyzing the cushion data. A secondary reason for not including the light usage cushions is that the value of the changes are of the same order of magnitude as the error in buoyancy testing.

Average % Buoyancy Loss vs. Thickness for All Types of Cushions With Severe Usage

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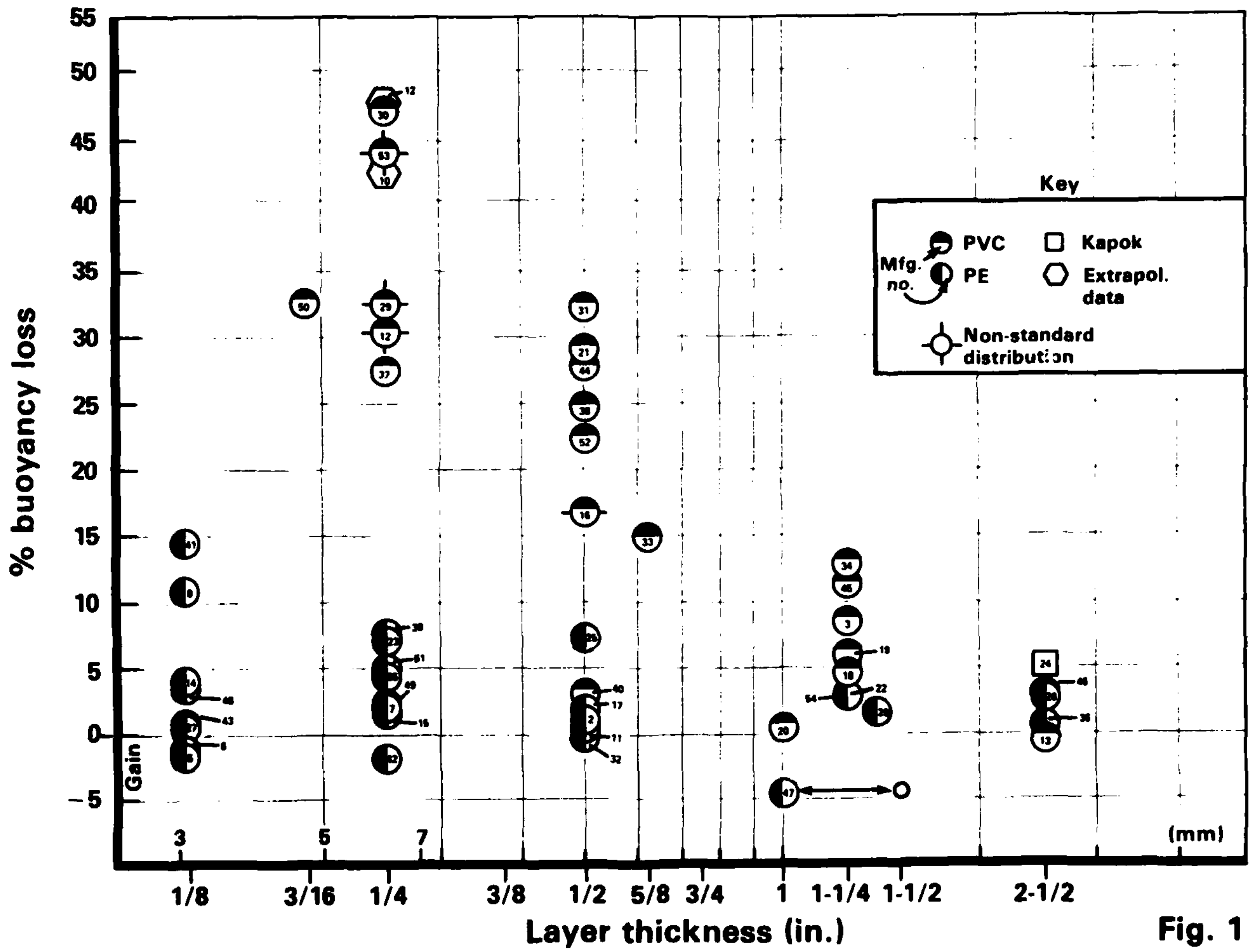

Fig. 1

5.3 Statistical Significance of Loss Data.

As stated, some of the non-standard constructions were definitely unacceptable if the results are statistically reliable. So, the next tasks were to determine whether there were statistically significant differences between the buoyancy losses for various materials and exactly what constitutes acceptable performance. The determination of significant difference was accomplished by running "t-tests" comparing the various average losses to a proposed acceptance limit of 6% loss. The results of this comparison are shown in Figure 2. It shows the majority of the materials above the line are significantly worse than the limit and the majority below the line are significantly better than the limit when testing at a 90% confidence level. The amount of spread for the materials which are not significantly different from the acceptance limit represents the band within which there is uncertainty about the results. The figure shows that there is a relatively small band of uncertainty and there are many materials above and below the acceptance limit and therefore are significantly better or worse respectively. Generally, PVC materials fall in the unacceptable area and PE in the acceptable. Keep in mind, however, that many of the PVC samples were of non-standard construction.

5.4 Acceptance Criteria Selection.

Selection of the acceptance limit was based on several factors. (1) Materials which meet the CG Subparts and which had been in service without problems should be acceptable (this includes most 1 inch thick and thicker PVC which have been produced for at least 5 years). (2) Materials which had been reported to have noticeable buoyancy losses in service in the past should be unacceptable (this included some extremely light weight PE). These two factors meant that the acceptance limit should fall between material codes #23 and #19 which had loss rates of 6.9 and 5.48 respectively.

The acceptance limit was also based on what the Coast Guard believed would provide an adequate buoyancy for the useful life of a foam filled device as determined by how long the straps and envelope fabric remain in good condition. It was estimated that with the more durable fabrics, webbings, and threads a device subjected to service similar to the test devices would last approximately 3 years. (Note: The test devices were made with the lightest materials available and some of the covers and straps were failing at the end of the single season.) If during this 3 year service a device lost buoyancy at the same rate as in the test, a minimally acceptable foam would have an 18% loss in buoyancy which is the maximum risk the Coast Guard believes is acceptable. These factors lead to the selection of 6% as the acceptance limit.

The above analysis on useful service life and continued loss involves several assumptions which are open to debate. Further discussion of these assumptions is in Section 4.2.

Average % Buoyancy Loss vs. Thickness for Cushions With Most Severe Usage Compared to 6% Acceptance Limit

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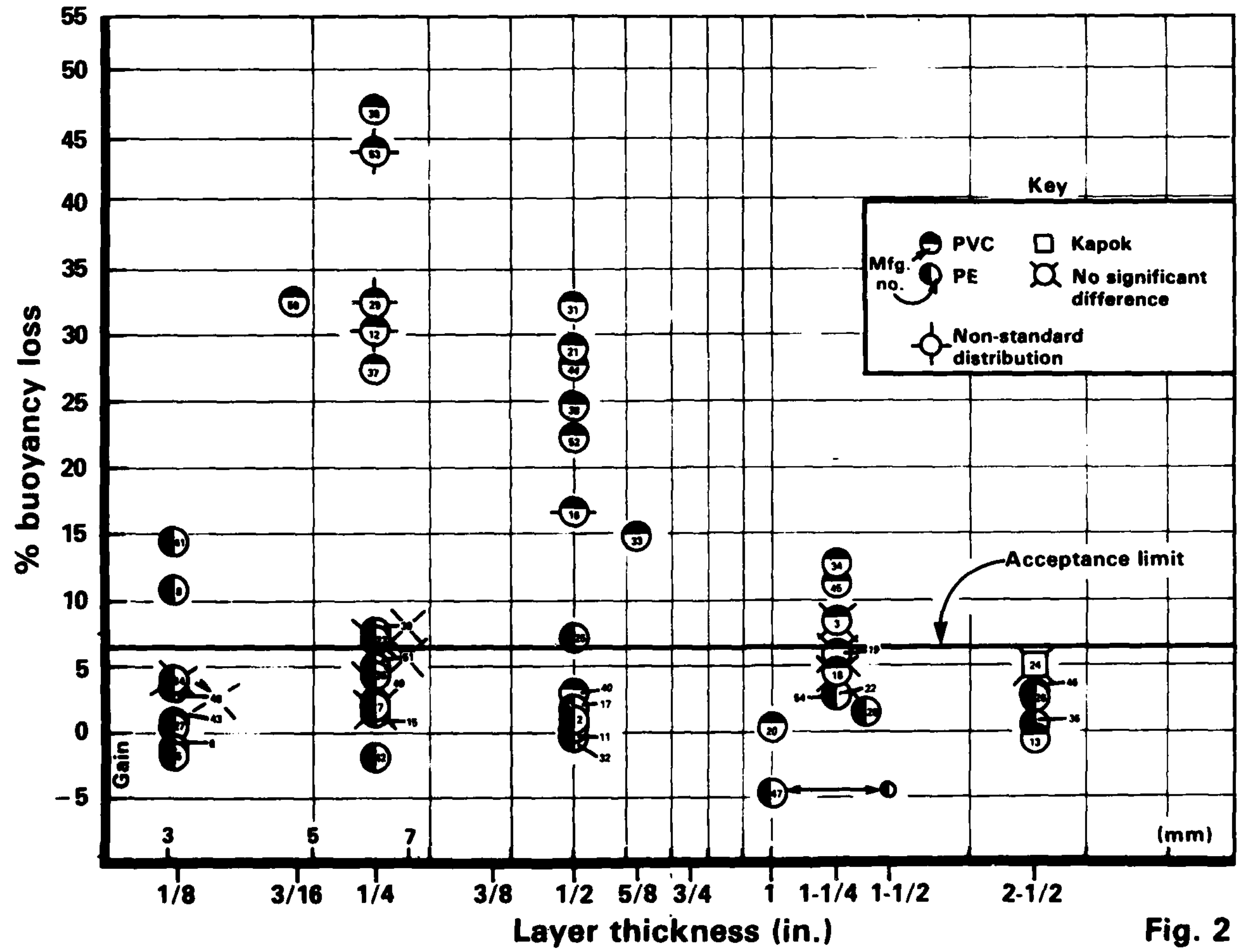


Fig. 2

5.5 Indicators of PFD Serviceability.

A finding in the overall analysis is that there is no clue to buoyancy loss provided by a foam device until approximately 50% of the buoyancy is lost. The field failures which were the catalyst for this program were the first devices which had been sent to the Coast Guard for reasons of suspected buoyancy loss. The losses measured for these devices were as high as 45%. Also, for all the field test devices (which had a full range of losses fairly evenly distributed from none up to 67% loss) most of the devices returned had a loss of from 40 to 67%. The other three devices returned had losses of 29, 32, and 36% and very significant weight gains. Many other devices with losses between 25 and 56% were not returned until the completion of the test even though the users had specifically been requested to be mindful of the condition of the cushions, and the devices were specially labeled requesting that they be returned if they appeared unserviceable. This lack of serviceability clues leads to the failure modes and effects analysis discussed later.

5.6 Assignment of Curves of Best Fit.

The data was also analyzed to try to determine the curve of best fit for average buoyancy loss vs. thickness for each family of material. An example of some of the types of curves tried is shown in Figure 3. As shown in this figure, interpolated values for thicknesses between maximum and minimum thicknesses tested can be determined with reasonable accuracy. On the other hand, the type of curves used vary widely outside of the data points. Therefore, extrapolated values for thicknesses outside the range of thicknesses tested cannot be accurately determined. Figure 3 shows only the exponential curve and the logarithmic curve. Other curve types were tried, however, the logarithmic curve is the most reasonable for the families of materials in the test program. Figure 4 shows the families of materials tested plotted on semi-log paper along with two idealized characteristic curves showing how the thickness/loss relationship is believed to change with two products of different durability.

5.7 Vest Results.

The data for vest buoyancy losses is shown on Figure 5. Due primarily to the measurement error of the data, no trends relating buoyancy loss to thickness for PE foams used in vests can be determined. For PVC foams, even though there was a limited amount of data collected, the same trends relating buoyancy loss to thickness for this material when used in cushions can be used for vests. It is apparent that the PE foams had less buoyancy loss than the PVC foams tested. The results for vests also showed that multiple layers of either foam performed about the same as single layer constructions of the same thickness of the individual layers. This will be explained in more detail in section 5.8. Again, the 6% acceptance criteria was used to determine acceptable foams.

Average % Buoyancy Loss
vs.
Thickness for the PVC Foam With Code Numbers
50, 37, 16, & 18

4-30-82

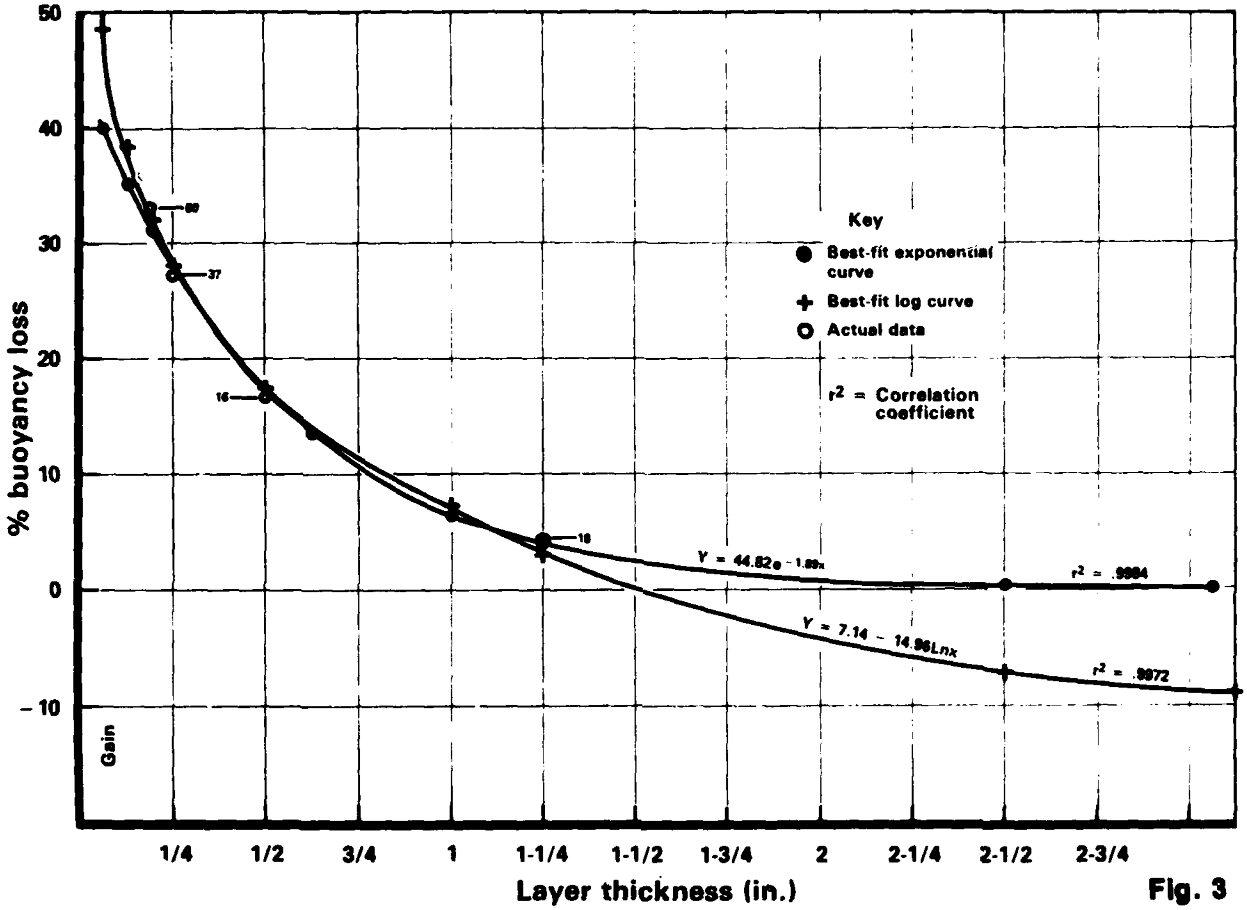


Fig. 3

Average % Buoyancy Loss vs. Thickness for Cushions With Severe Usage Showing Characteristic Curves

4-30-82

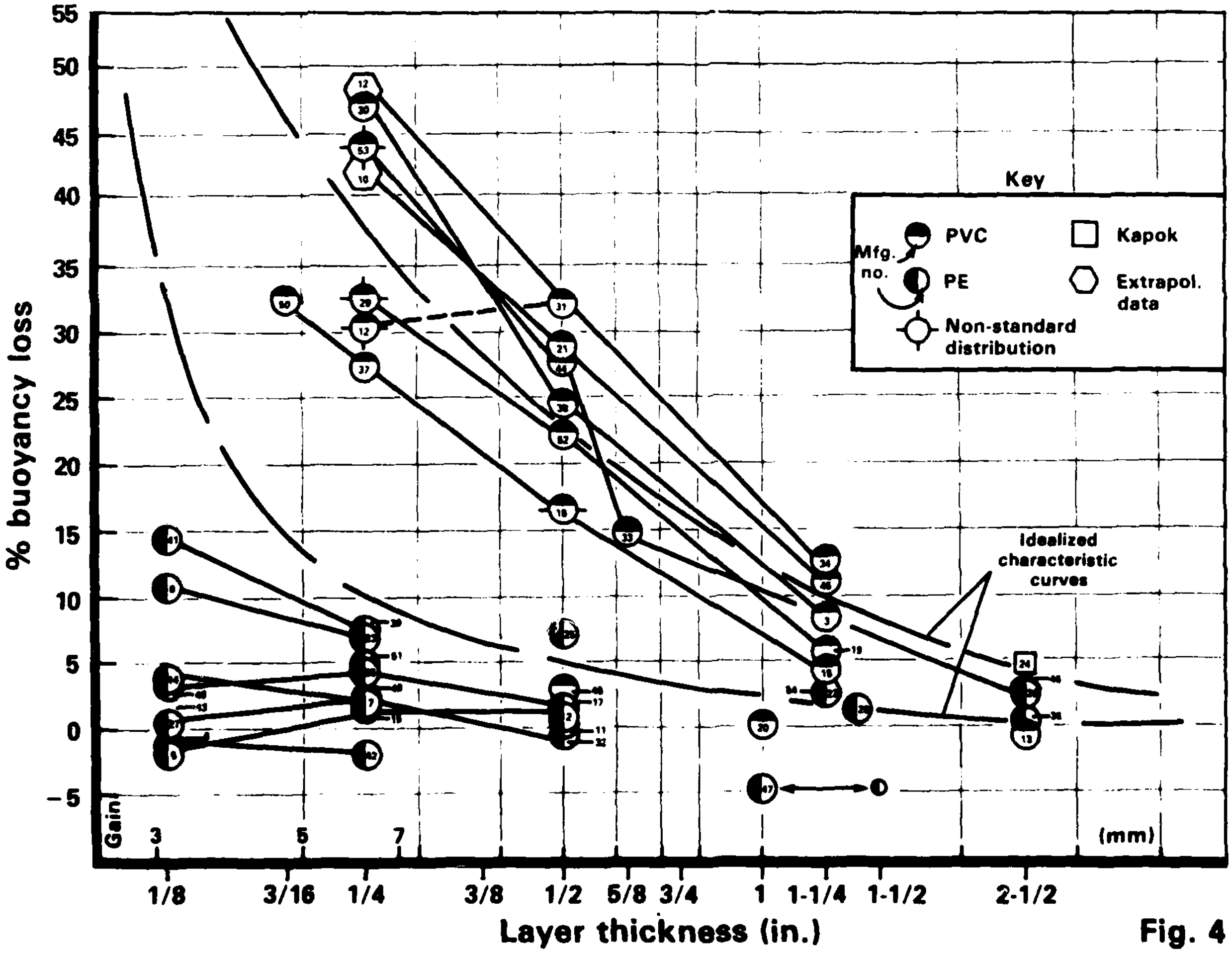


Fig. 4

Average % Buoyancy Loss vs. Thickness for All Vests

5-3-82

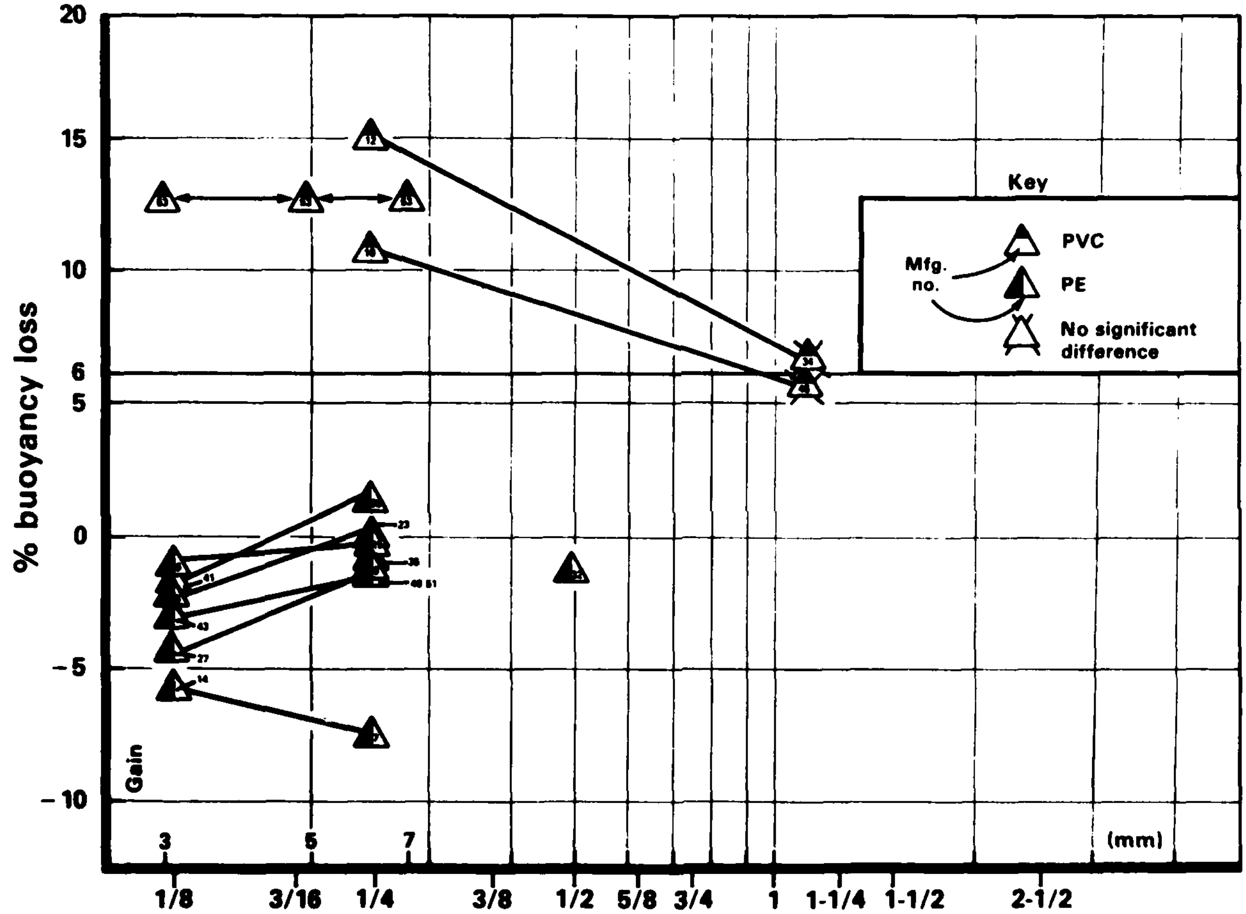


Fig. 5

5.8 Cushion/Vest Correlation.

As stated previously, the fact that cushions are not made with layers of thin gauge PVC material does not make the cushion data for these materials worthless. Its value is in having a field test method to get an accelerated look at how a material will perform in a vest. Looking at the two PVC materials with a nominal 1 inch thickness that were tested in both cushions and vests there is a 2 to 1 relation of cushion loss to vest loss respectively (see Figure 6). This relationship, however, is probably not constant with respect to thickness.

There were three approximately 1/4" PVC materials tested in wearable PFDs and cushions. The one material which yielded the most straightforward result was tested with ten 1/4 inch sheets in cushions and single layer combination of 3, 5, and 7mm material in float coats. The loss relationship was 3.5 to 1 for cushions to coats respectively. It should be noted that only 3 samples made up the cushion average due to the other samples having insufficient initial buoyancy to be distributed to the severe use locations. The average for these cushions, however, falls in line with the characteristic curve for PVC materials.

The other two 1/4" PVCs tested in both cushions and vest had no good cushion data from severe use liveries. Thus, there are only extrapolated values available for comparison. However, based on the other thicknesses tested in cushions it can be seen in Figure 4 that all three of these materials have similar losses with perhaps Code #53 having slightly less loss. The loss relationship for these two PVC foams is 3.2 to 1 and 3.8 to 1.

Even though it would be preferable not to draw conclusions on this extrapolated data, there is a very important relationship to be established and since the curves for all PVC materials show the same characteristic losses it is reasonable to do so. The important point is that when tested in vests, the layering of the materials has not greatly affected the results in this test program. If the vests had been made wet more often and tested in a warmer environment, the layering might be expected to cause greater losses.

It should be noted that while it is now believed that there is a difference in losses for vests and cushions, the vests were subjected to a relatively less severe test than the cushions. Had the vests been subjected to the same relative severity as cushions, it would be expected that the losses experienced with the thinner materials would have been increased by a greater percentage than the thicker ones.

Because vest field testing may be less repeatable than cushion testing and because of the lack of vest data at present, the (average) loss relationship selected for vests to cushion was 3 to 1 at 1/4" thickness, 2.5 to 1 at 1/2" and 2 to 1 at 1" and greater. Intermediate values were derived by interpolation.

Average % Buoyancy Loss vs. Thickness for Selected Cushions With Most Severe Usage and Selected Vests

5-3-82

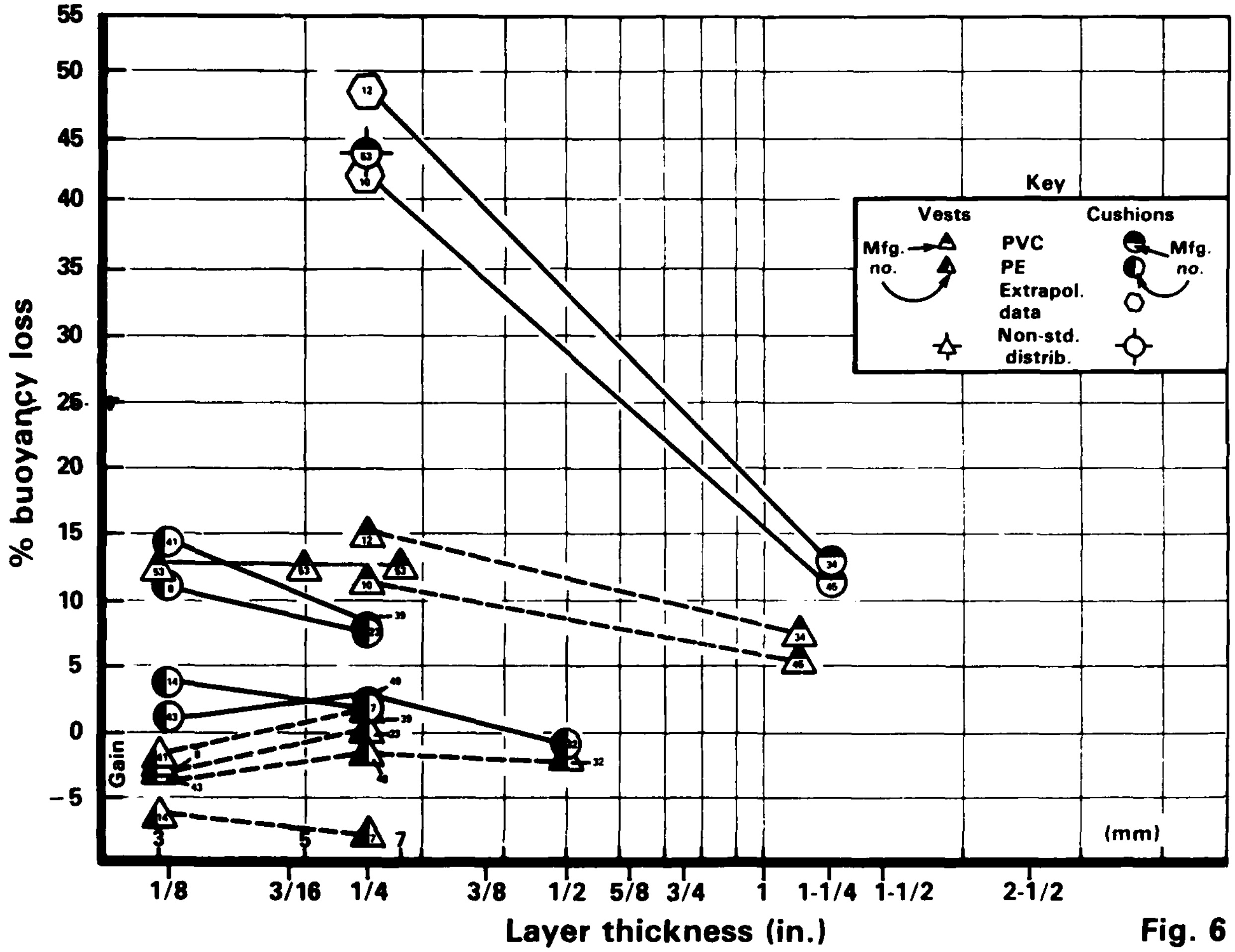


Fig. 6

5.9. Failure Mode and Effects Analysis.

In evaluating the reliability of flotation materials, the failure mode and its effect on the use (or replacement) of the device must be considered. Figure 7 illustrates the difference with time in the buoyancy provided by a group of foam cushions with a 6% loss rate and a group of kapok cushions. The basis for the first year shown is the data for representative samples from the field test. Note that the average loss given earlier for kapok included all ten devices even though two of them had been taken out of service. The later years are extrapolated based on the assumptions stated earlier. The important difference in the long range average buoyancy other than the loss rates is the difference in failure mode.

When the kapok device "fails" (gets a hole in the insert pad cover) there is a relatively rapid increment of buoyancy loss and readily detectable changes in characteristics of the device whether it be a significant weight gain, development of mildew odor, change in firmness or hardness of the device, and/or development of lumpiness. Because of these obvious changes the vast majority of these "failures" are replaced. Aside from the devices which had insert pad covers with a hole, there is a slight increment of buoyancy loss due to aging.

Thus, the average buoyancy of the kapok devices after some period of time is made up of two groups of devices, one with slight changes in buoyancy due to aging and the other with holes in the plastic inserts which have not yet been replaced. From unpublished research it is estimated that at any given time 3.2% of kapok devices in actual use fall in this group of devices with holes in the inserts. From the present test and past investigations, the buoyancy loss of a holed device has been shown to be about 18% to 20%. These devices with open inserts make up the inconsistancy in the lower side of the distribution curves for the kapok devices shown in Figure 7.

For the particular foam device shown, the average buoyancy loss after three years is equal to the loss of the small percentage of kapok devices with holes. The distribution of buoyancies of foam devices is much wider than kapok in addition to the population having a much lower average buoyancy. These two factors result in a significantly higher probability of finding a device made from this particular foam having well over 20% buoyancy loss. The inability to recognize buoyancy loss in foam devices is a distinct disadvantage.

Failure Mode Profile Comparison for Foam and Kapok Devices (Average Buoyancy vs. Time)

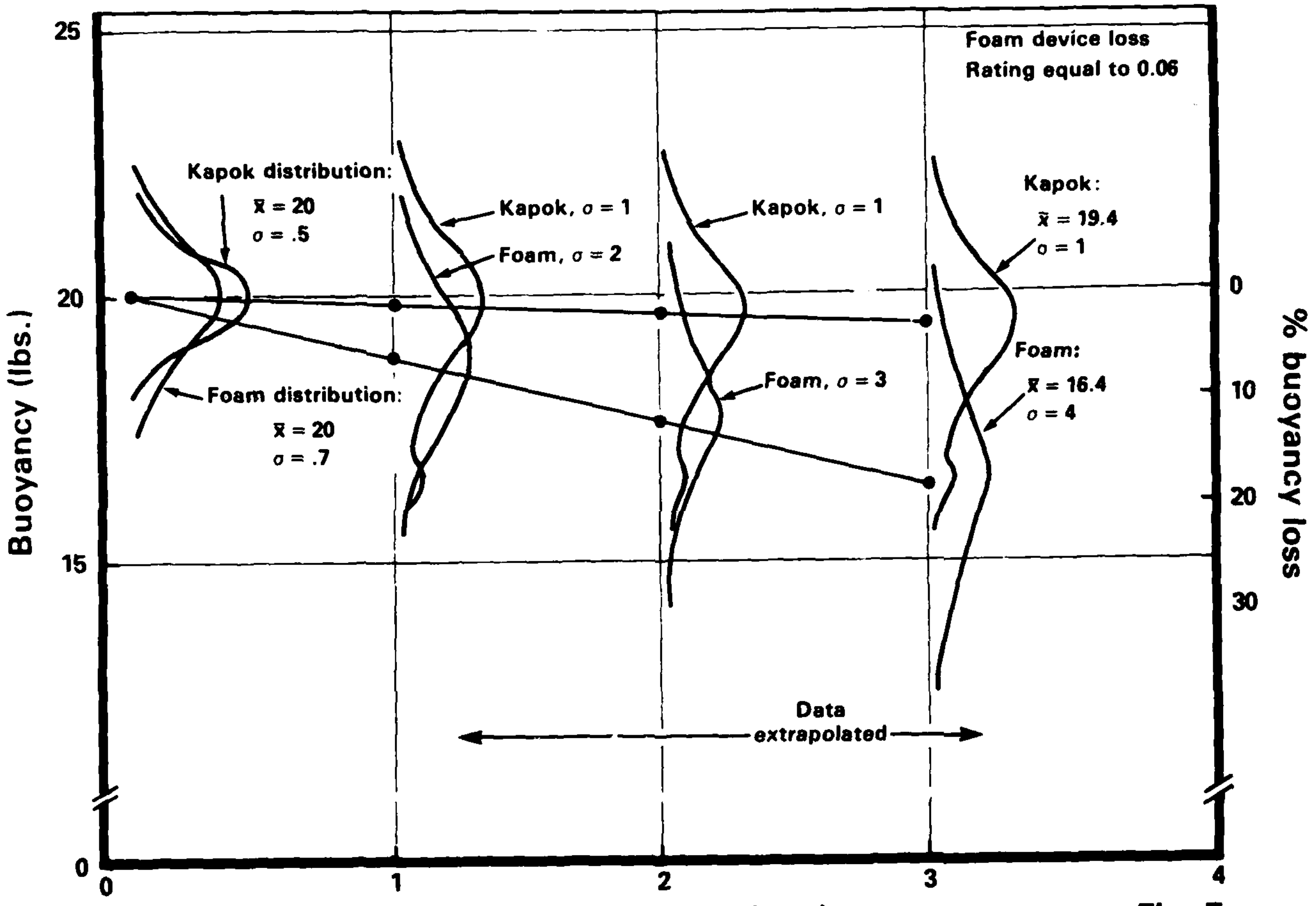


Fig. 7

5.10 Determination of Supplemental Buoyancy and Total Buoyancy Required in a New PFD.

In order to determine how much buoyancy is required in a new PFD to ensure that after 3 years of hard use it will still have enough buoyancy to ensure safety, the loss rate for the buoyant material must be determined. For either cushions or vests the losses from field usage provide an estimate. In order to compensate for these buoyancy losses, some supplemental buoyancy must be added to the device. To determine the supplemental buoyancy, the regulatory minimum buoyancy must be multiplied by some factor dependent upon the loss rate. The mathmatical derivation for the multiplier, supplemental buoyancy and total buoyancy required for the device when new, is shown below. The 18% maximum loss used in the analysis is discussed in section 5.4. These calculations have been performed for a wide range of loss ratings and the results are shown in Figure 8.

DERIVATION OF REQUIRED SUPPLEMENTAL AND TOTAL BUOYANCY

B_o = Regulatory Minimum Buoyancy
B_t = Initial Total Buoyancy of the Device Unsupplemented
B_s = Total Buoyancy of the Device with Supplemental Material
M = Loss Multiplier
L = Predicted Loss Rate Per Season
S = Supplemental Buoyancy Required to Meet 18% Maximum Loss

$$S = (B_o)(M)$$
$$B_s = B_o + S = B_o + (B_o)(M)$$

Given that the remaining buoyancy after 3 years usage is:

$B_o - .18(B_o)$ for unsupplemented materials and
$B_s - 3(B_s)(L)$ for supplemented materials.

Then

$$B_o - .18(B_o) = B_s - 3(B_s)(L),$$

if the remaining buoyancy is to be the same, which is the desired result.

Given $B_o - .18(B_o) = B_s - 3(B_s)(L)$

$$B_o(.82) = B_s(1 - 3L)$$

$$\therefore \quad B_s = \frac{B_o(.82)}{1 - 3L}$$

To determine the Loss Multiplier, M

$$\frac{B_o(.82)}{1 - 3L} = B_o + (B_o)(M)$$

$$\therefore \quad M = \frac{.82}{1 - 3L} - 1 \qquad \text{For } L < 33\%$$

FOAM BUOYANCY CORRECTIONS

L	B_o = 15.5		B_o = 11.0		B_o = 7.0	
% Loss	S(lbs.)	B_t(lbs.)	S(lbs.)	B_t(lbs.)	S(lbs.)	B_t(lbs.)
6.5	0.3	15.8	0.2	11.2	0.1	7.1
7.0	0.6	16.1	0.4	11.4	0.3	7.3
7.5	0.9	16.4	0.6	11.6	0.4	7.4
8.0	1.2	16.7	0.9	11.9	0.6	7.6
8.5	1.6	17.1	1.1	12.1	0.7	7.7
9.0	1.9	17.4	1.4	12.4	0.9	7.9
9.5	2.3	17.8	1.6	12.6	1.0	8.0
10.0	2.7	18.2	1.9	12.9	1.2	8.2
10.5	3.1	18.6	2.2	13.2	1.4	8.4
11.0	3.5	19.0	2.5	13.5	1.6	8.6
11.5	3.9	19.4	2.8	13.8	1.8	8.8
12.0	4.4	19.9	3.1	14.1	2.0	9.0
12.5	4.8	20.3	3.4	14.4	2.2	9.2
13.0	5.3	20.8	3.8	14.8	2.4	9.4
13.5	5.9	21.4	4.2	15.2	2.6	9.6
14.0	6.4	21.9	4.6	15.6	2.9	9.9
14.5	7.0	22.5	5.0	16.0	3.2	10.2
15.0	7.6	23.1	5.4	16.4	3.4	10.4
15.5	8.3	23.8	5.9	16.9	3.7	10.7
16.0	8.9	24.4	6.3	17.3	4.0	11.0
16.5	9.7	25.2	6.9	17.9	4.4	11.4
20.0	16.3	31.8	11.6	22.6	7.3	14.3
25.0	35.3	50.8	25.1	36.1	16.0	23.0
30.0	111.6	127.1	79.2	90.2	50.4	57.4

FIG. 8

5.11 Buoyancy Testing Repeatability.

Part of the program plan included testing to determine the repeatability of buoyancy testing methods. These tests were necessary because new methods of buoyancy measurement had to be developed to handle the tremendous volume of devices to be measured in a short time. It also needed to be known how much, if any, buoyancy loss might be attributed to the measurement error instead of the "real" changes due to the test usage.

In developing the new test method of buoyancy measurement, some representative samples were measured at various time intervals to determine at what interval the measured buoyancy stabilized. The results of this testing are shown in Table I. The range of variation in the results runs from 0.3% to 4.2% of the measured buoyancy. The soft PVC materials yielded the larger variations. This is probably due to either gradual hydraulic compression or water absorption or both. For all samples, there is some buoyancy change due to the gradual escape of trapped air but this change is not sufficient to warrant continuing the test beyond 2 hours. For some of the samples there are increases in buoyancy with time, indicating there are other variables effecting the results. In the test sequence run for the development of Table II, this same experiment was conducted in conjunction with the initial buoyancy test (test number 1) on each material and yielded similar results.

TABLE I

BUOYANCY CHANGE WITH TIME IN WATER

Type of Const.	Buoyancy After (lb/oz) 2 Hours	3 Hours	4 Hours	5 Hours	6 Hours	Max. Var. (oz)	% Var.	Std. Dev. (oz)
3/16" PVC	16/12	16/12	16/8	16/1	16/1	11	4.2	6
1/8" PE	22/5	22/6	22/5	22/5	22/6	1	0.3	1
1/2" PVC	19/12	19/15	19/14	19/8	19/8	7	2.2	3
1/2" PVC	18/6	18/2	18/2	18/2	18/3	4	1.4	2
3/16" PVC	18/9	18/10	18/10	18/12	18/10	3	1.0	1

The more important experiment was to take representative samples and run the 2 hour test developed above as separate tests. Table II presents the results of this testing. Ten samples were tested 4 times, once as received, the second time after 3 hours of air drying, the third after 72 hours of air drying, and the fourth was after various intervals, as the test was part of the regular initial buoyancy testing of the 1188 samples. The variation in results run from 1.2% to 7.7% of the average measured buoyancy. The three results which are marked with an asterisk are so out of character with the rest of the data that one would think that there was a recording error. However, these types of blunders are a

possible part of the variations so they are included in the percentages shown. It should be noted that these three readings occur in the samples with the highest percentage of variation. In the analysis of the field data a number of similar results were discovered and the devices were then retested and the results corrected.

TABLE II

Repeatability Test Sequence

Type of Const.	Buoyancy for Test Number 1	2	3	4	Var.	% Var.	Average Buoyancy	Std. Dev.
		(lb/oz)			(oz)		(lb)	(lb)
1/8" PE	22/10	22/5	22/9	22/9	5	1.4	22.52	0.14
1/4" PE	15/15	15/12	15/12	15/12	3	1.2	15.80	0.10
1/4" PVC	16/12*	15/12	15/11	15/11	17	6.7	15.97	0.52
1/4" PE	19/00	18/14	19/7	19/14	16	5.2	19.30	0.46
Kapok	22/14	23/00	23/8	22/15	10	2.7	23.08	0.28
1/4" PVC	17/10	17/2	17/6	17/7	8	2.9	17.40	0.21
1/2" PE	21/10	21/13	20/11*	21/15	21	6.1	21.52	0.57
1/8" PE	19/00	18/15	19/9	20/00	17	5.4	19.38	0.50
1/8" PE	16/8	16/6	16/13	18/11*	21	7.7	17.10	1.08
1/2" PVC	19/4	19/00	19/3	19/5	5	1.6	19.19	0.13

Statistical analysis of this data indicates that 3.7 percentage points of any individual cushion's percent change in buoyancy might be attributed to test variation (using a 90% confidence interval). When ten samples are averaged together as they were in this study, the mean (average) percent loss will be within 1.9 percentage points of the true value in most cases. For the sake of this analysis the three results with asterisks were deleted because such blunders can be and were identified and retested. It does not appear that the variation is any greater for any one particular type of flotation material as opposed to another.

6. CONCLUSIONS

From the analysis of the data, several conclusions can be made. It is obvious that since the data came from field usage, the test results are representative of some types of actual field use conditions. The results obtained provided sufficient data to allow UL to prepare a revised performance standard.

It can be derived from section 5.2 that buoyancy losses in flotation foam are clearly related to the usage of the foam. If this were not the case, all test liveries data would be approximately equal for the same foams. The statistical analysis indicated that the magnitude of loss for each type of material was a function of the use location.

Section 5.8 indicates that vests do not receive the same severity of usage as cushions. However, it can be concluded from section 5.8 that the vests and cushion loss rates are related. Therefore, the assignment of a buoyancy loss rating for a material which will be used in a vest can be obtained using cushion data. More analysis is needed to more acurately determine the exact relationship between vest and cushion buoyancy losses.

Many of the different types of flotation materials tested had significantly different buoyancy loss rates from each other for the same use condition. By conducting tests, loss rates for a particular family of materials can be assigned. These loss rates can be estimated for a specified period of time. The estimated loss rates are extrapolated from the available test data. Within a family, a determinating factor of the loss rate is the thickness for PVC materials.

The service life of a PFD is dependent largely on the durability of the component materials. When the service life is assumed to be approximately 3 years as was mentioned in section 5.4, only the flotation materials which lose 6% or less of their buoyancy per year would be considered by the Coast Guard to provide adequate serviceability. However, those materials which lose more than 6% of their buoyancy per year could provide adequate serviceability with the addition of sufficient supplemental buoyant material.

The small number of early sample returns shows that buoyancy losses in foam devices are not readily apparent until approximately 50% loss occurs. In conjunction with this, section 5.9 indicates that the failure mode for foam materials is a gradual process due to wear and aging. Therefore, a user of a foam PFD will not realize that his/her PFD has lost a significant portion of its buoyancy unless the device is tried out in the water. In comparison, kapok PFDs have a relatively rapid increment of loss if the insert pad cover gets a hole. This is not to say that the device has a total failure similar to puncturing the bladder on an inflatable device. The rapid buoyancy loss of these kapok devices is a plus factor which serves to indicate a problem with the PFD but stops at a maximum of about 20% of the initial buoyancy of the device until another insert is damaged.

Characteristic curves can be assigned to families of materials for buoyancy loss vs. thickness. These curves allow intermediate thicknesses to be assigned buoyancy loss ratings by interpolating the values obtained by testing.

It can also be concluded that the buoyancy test method used for this study is repeatable enough that values for significant buoyancy losses (greater than 2%) can be determined from a single season study such as this one.

Based on the analysis in this report, it can be concluded that supplemental buoyancy can be added to foam PFDs to compensate for the losses due to aging and severe use. However, this supplemental buoyancy is only practical up to about a 15% loss rate and is theoretically impossible over a 33% loss rate by the equation given on page 20.

REFERENCES

a. Report of Meeting between USCG, UL, and flotation foam manufacturers, held on 15 December 1981 at USCG Headquarters, Washington, DC. Copies available from either USCG or UL.

b. First Progress Report on the Flotation Foam Field Test, dated 30 June 1981, retyped 30 July 1981. Copies available from either USCG or UL.

c. Second Progress Report on the Flotation Foam Field Test, dated 24 August 1981. Copies available from either USCG or UL.

d. Third Progress Report on the Flotation Foam Field Test, dated 15 January 1982. Copies available from either USCG or UL.

e. Doll, T.J. et al., Personal Flotation Devices Research - Phase II, Wyle Laboratories, January 1978, NTIS No. AD-A037 221/9GA; Available from the National Technical Information Service, Springfield, Virginia 22161.

APPENDICIES

Taken from: UL letter dated 27 March, 1981, transmitting the Minutes of the Meeting Between United States Coast Guard and Flotation Foam Manufacturers of March 17th, 1981.

APPENDIX A

Field Test Program for PFD Flotation Materials

1. Background:

As stated in the CG letter of October 29th, 1980 there have been problems with certain polyethylene foams in PFD's. Foam materials have been accepted as equivalent to the required standards under UL 1191. Verification that materials meeting this standard are suitable in actual services needs to be established. To obtain more data on the problem and to provide for revision of the standard, the following test program is proposed for the 1981 boating season.

2. Test Objectives:

There are three goals to this program:

(a) Verify whether material meeting revised UL 1191 are suitable in service.

(b) To determine whether significant losses of buoyancy occur among the flotation material brands/types used in the field test.

(c) To determine whether the natural aging which will occur during the field tests can be simulated by an accelerated aging sequence.

3. Test Plan:

Materials:

The following manufacturers intend to participate by including their flotation materials in the program:

1. Packaging Industries
2. Voltek
3. Dow
4. Uniroyal
5. Airex
6. Jiffy
7. Housatonic
8. United Foam Plastics

Each brand or type of flotation material used for samples shall be from the same lot and production run and shall be identified as to the date of manufacture, lot number, type and source. Mr. Lemley will obtain kapok samples.

4. Material Samples:

4.1 - Five material specimens will be taken from each of the materials to be included in the program. Each specimen will be subjected to the initial tests (Paragraph 6) and the accelerated aging test (Paragraph 10). Note, the specimen must be plied up to one inch thickness for the accelerated aging test. In the case of the foam materials, the five specimens will come from different locations throughout the length of the roll or lot. In the case of the kapok, five sets of inserts will be selected at random.

4.2 - Additionally, three square yards of material selected from various parts of the same roll/lot will be necessary for performing updated UL 1191 tests.

5. Sample Cushions:

The remainder of each material will be used to make up 22 sample cushions. Each sample cushion will be subjected to an initial test, then 20 of the cushions made from each material will be subjected to a field test. One of the remaining two cushions will be retained by UL/MD and the other will be sent to USCG headquarters. Sample cushions will be constructed as follows:

Size: 15 x 15 x 2-1/2 inches

Cover: Uncoated, 70 denier nylon, 104 x 88 orange

(Four kapok inserts will be used in each sample kapok cushion)

Note: Some manufacturers may desire to include vests in the program. If they do, they must include the same materials in cushions.

6. Initial Tests (For Identification):

	Tests On		
	Each Sample Cushion	Each Material Specimen	
Weight of unit	X		
Buoyancy* (Displacement for kapok)	X	X**	buoy.
Density		X	wt. vol.
Compression set (last)		X	
Compression resistance		X	
Cell size		X	
Bulk processed buoyancy (kapok)		X	

* - To be tested twice by different technicians.
** - To be tested by Displacement Method.

7. Field Test Sample Cushion Or Vest Distribution And Test Environment:

Details of distribution and exact use guidelines require further work.

Ideally, the same number of units from each test sample should be subjected to each test environment. Contemplated test environments include liveries located in Long Island, Tampa, and Ohio. The length of use will be roughly the '81 boating season.

Rather than try to keep records of the usage of the units at liveries, it is anticipated that each livery will be given only as many units as can be kept in relatively continuous service and that a system of keeping the cushions in rotation will be developed.

A general description of each use environment will be requested.

8. Final Tests Of Samples From Field Test:

Each unit will be tested for buoyancy (displacement in case of kapok devices) after the field usage and the percent loss will be determined.

9. Reference Sample Cushions:

It is anticipated that the reference sample at UL will be placed on a roof in continuous outdoor exposure and the USCG sample stored in an air conditioned space.

10. Lab Test (Accelerated Aging Sequence):

After the initial tests, each material sample will be subjected to the Schedule 1 accelerated aging sequence with the samples plied up to one inch thickness.

ATTACHMENT 1

Durability Testing of Flotation Foams for PFD's

Schedule 1 - Accelerated Aging Cycle

Tests:

(a) Buoyancy - in accordance with UL 1191

(b) Volume - by displacement method

(c) Heat Aging - 42 hours at 60°C

(d) Humidity - 21 hours at 95% relative humidity

(e) Sunlight (UV) - 126 hours or 8845 langeys at 60°C (represents one year exposure during intermittent use)

(f) Abrasion/Compression - 50 minutes at 11 Hz and 1 cm displacement (0.4 in.) loaded with a 16 x 18 in. canvas bag containing 75 lbs of shot. A rectangular shaped jig is mounted to a vibration table to facilitate this test.

(g) Buoyancy - as Item (a) above

(h) Volume - by displacement method

Samples:

Each individual sample is to be a 16 x 9 inch rectangle of ~~the~~ one inch ~~with~~ thickness. Materials of less than one inch shall be plied up to one inch thickness. Materials thicker than one inch shall be skived down to one inch thickness.

Two sample sets are to be tested of each foam included in program.

Run with samples from sets fastened together

Five individual samples ~~pieces~~ are required for each sample set to be tested. One sample set shall be covered with an international orange uncoated 70 denier, 104 x 69 count nylon fabric. One sample set shall be covered with a course black white netting. It may be necessary to stitch specimens together to hold parts together.

Calculation:

Calculate the loss in buoyancy between Items (a) and (g).

Note: Samples will go from one test to another with no significant delay between tests.

APPENDIX B

Foam Manufacturers Participating in the Field Test

Cellu Products Company
Post Office Box 98
Patterson, North Carolina 28661
Attn: Mr. Albert Galbraith

*****

Dow Chemical, U.S.A.
Post Office Box 515
Granville, Ohio 43023
Attn: Mr. Gary Miller

*****

Housatonic Ever-Float Co., Inc.
Post Office Box 529
Shelton, Connecticut 06484
Attn: Mr. Cornell Kress

*****

Jiffy Manufacturing Company
237 Ridge Ave.
Hanover, Pennsylvania 17331
Attn: Mr. Peter Robinson

*****

Lonza, Inc.
Airex Division
22-10 Route 208
Fairlawn, New Jersey 07410
Attn: Mr. Ron Brandt

Rubatex Corporation
Railroad Ave.
Bedford, Virginia 24523
Attn: Mr. Glenn DeLong

*****

Sentinel Foam Products, Inc.
Post Office Box "S"
Hyannis, Massachusetts 02601
Attn: Mr. Dennis Knaus

*****

Uniroyal, Inc.
312 North Hill St.
Mishawaka, Indiana 46544
Attn: Mr. W. J. McCracken

*****

United Foam Plastics Corp.
172 East Main St.
Georgetown, Maryland 01833
Attn: Mr. Bill Shaw

*****

Voltek, Inc.
100 Shepard St.
Lawrence, Massachusetts 01843
Attn: Mr. Ray Pleiness

APPENDIX C

List of Liveries Participating in the Field Test

1. Liveries using cushions

Alafia River Outpost
Rt. 1, Box 414 K
Valrico, Florida 33594
Attn: Mr. Rich Still

*****

Cypress Gardens
Winterhaven, Florida 33880
Attn: Mr. Val Darling

*****

Fletcher's Boat House
5022 Cathedral Ave. NW
Washington, DC 20016
Attn: Mr. Fletcher

*****

Government Services Inc.
1101 W St. SE
Washington, DC 20020
Attn: Mr. Richard Rode

*****

Lenny's Boat and Motor Rental Inc.
74 West Shore Dr.
Avon Lake, Ohio 44012
Attn: Mr. Dvorak

*****

Little Manatee River Outpost
18001 U.S. Highway 301 South
Riverview, Florida 33569
Attn: Ms. Fay Wood

Marine Rest
72 Foster Ave.
Hampton Bays, Long Island
New York 11946
Attn: Mr. Jim Hutchinson

*****

Oakhaven Fish Camp
12143 River Hills Dr.
Tampa, Florida 33617
Attn: Ms. Vicki Tangney

*****

Osker's Fishing Station
91 Foster Ave.
Hampton Bays, Long Island
New York 11946
Attn: Mr. Bob Russo

*****

Peace River Outpost
Route 7, Box 301
Arcadia, Florida 33821
Attn: Ms. Charlotte Bragge

*****

Walt Disney World Co.
Post Office Box 40
Lake Buena Vista, Fl. 32830
Attn: Mr. Wayne L. Michell

*****

Withlacoochee River Outpost
Post Office Box 188
Nobleton, Florida 33554
Attn: Mr. George Blust

2. Liveries using vests

Chapman
410 Hickory St.
Warren, Pennsylvania 16365
Attn: Mr. James B. Kemp

*****

Dymatuning
R.D. #1
Dauphin, Pennsylvania 17018
Attn: Mr. Thomas M. Irons

*****

Hills Creek
Post Office Box 253
Wellsboro, Pennsylvania 16901
Attn: Mr. & Mrs. Wm Boroch

*****

M.K. Goddard
347 Main St.
Greenville, Pennsylvania 16125
Attn: Mr. Joseph N. Perry

Moraine
506 N. McKean St.
Butler, Pennsylvania 16001
Attn: Ms. Diane L. Rapp

*****

Nockamixon
Bethlehem Motorboat Sales
Route 378, R.D. #3
Bethlehem, Pa. 18015

*****

Presque Isle
297 Market St.
Clearfield, Pa. 16830
Attn: Mr. Louis P. Stefan

*****

Prince Gallitzin
Road 435 Sunshine A
Central City, Pa. 15926
Attn: Mr. Pete A. Yelovich

APPENDIX D

Taken from: First Progress Report on Field Test Program of Flotation Material, dated 30 July, 1981 from Underwriters Laboratories.

Sample Construction Process.

1. On April 30th and May 1st, Mr. Richard Bogue and Mr. Sam Wehr visited the Ero Manufacturing facility at Hazlehurst, Georgia and set-up the initial production line for the test samples. Mr. Sam Wehr remained at the manufacturing facility until May 2nd, 1981. The production line consisted of:

   (a) Manufacturing 2 special templates. These were made of heavy mylar with 1/8 inch holes drilled along the outline of the foam material.

   (b) Marking the necessary number of labels with the manufacturers code number.

   (c) Sewing of the initial buoyant cushion shells to include the attachment of the label (supervised by Mr. Ralph Steger).

   (d) Sewing of the 9 inch (23cm) by 16 inch (41cm) 70 denier and netting shells for the accelerated aging sequence test samples (supervised by Mr. Sam Wehr). This sewing included the attachment of 1/2 of a label.

   (e) Laying up and cutting all of the PVC foam.

   (f) Sampling of this foam.

   (g) Assembly of approximately 19 sample groups.

2. On the 5th of May, Mr. Tom Carr, pursuant to the instructions to continue to sample the assembly of the foam test samples at the USCG designated manufacturer arrived at Ero Manufacturing Company. There he supervised and assisted in the following manufacturing procedure:

   (a) Select foam from submitted samples and record the manufacturer's name, code number and material type (sheet, block, etc.) and size (1/2 inch, etc.).

   (b) Ply foam to 5 inches and lay appropriate template on it.

   (c) Mark foam by using chalk duster.

   (d) Have foam cut with material cutting saw.

(e) Mark all pieces. There was a special marking convention established whereby the one-foot squares from the cushion lay-ups were marked with the code number and the type of material, as opposed to the special sample lay-ups which were only marked with the code number. (This was done so that the samples from within the cushions could be identified and included in the identification tests.) This included pieces: 15 inches (38cm) by 15 inches (38cm) by 2½ inches (nominal plied) (63mm); 12 inches (31cm) by 12 inches (31cm); 9 inches (23cm) by 16 inches (41cm); and 4 inches (10cm) by 4 inches (10cm).

(f) Supervise the "stuffing" of the cushion shells with 15 $inch^2$ ($0.15m^2$) foam pieces and the stuffing of the accelerated aging sequence shells with 9 inch (23cm) by 16 inch (41cm) foam pieces.

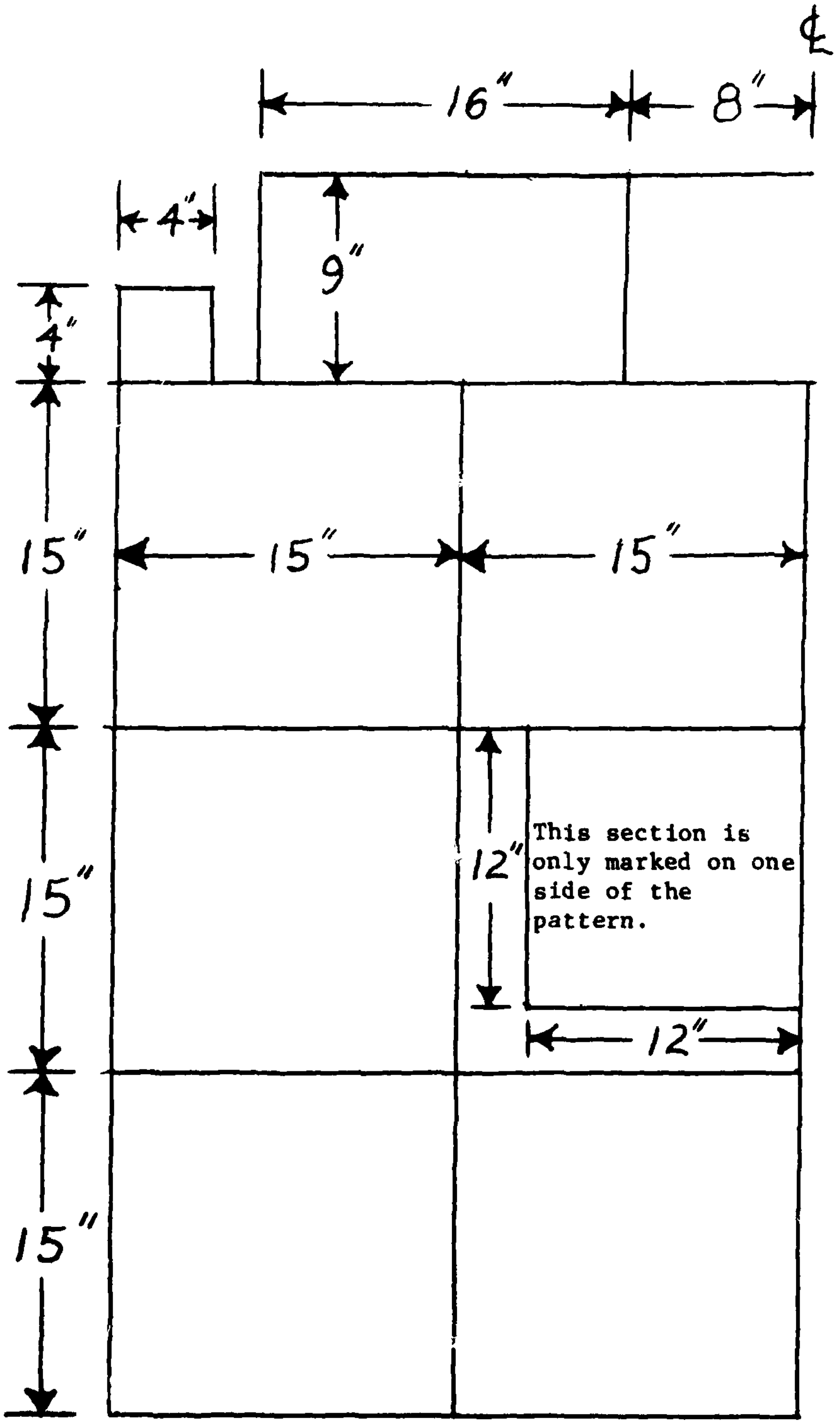
(g) Put all other foam pieces in blue polyethylene bags.

(h) Supervise the sewing of the closing seam of all shells.

FOAM CUTTING TEMPLATE #1

(Half of Pattern, Flip over about ℄ for other half)

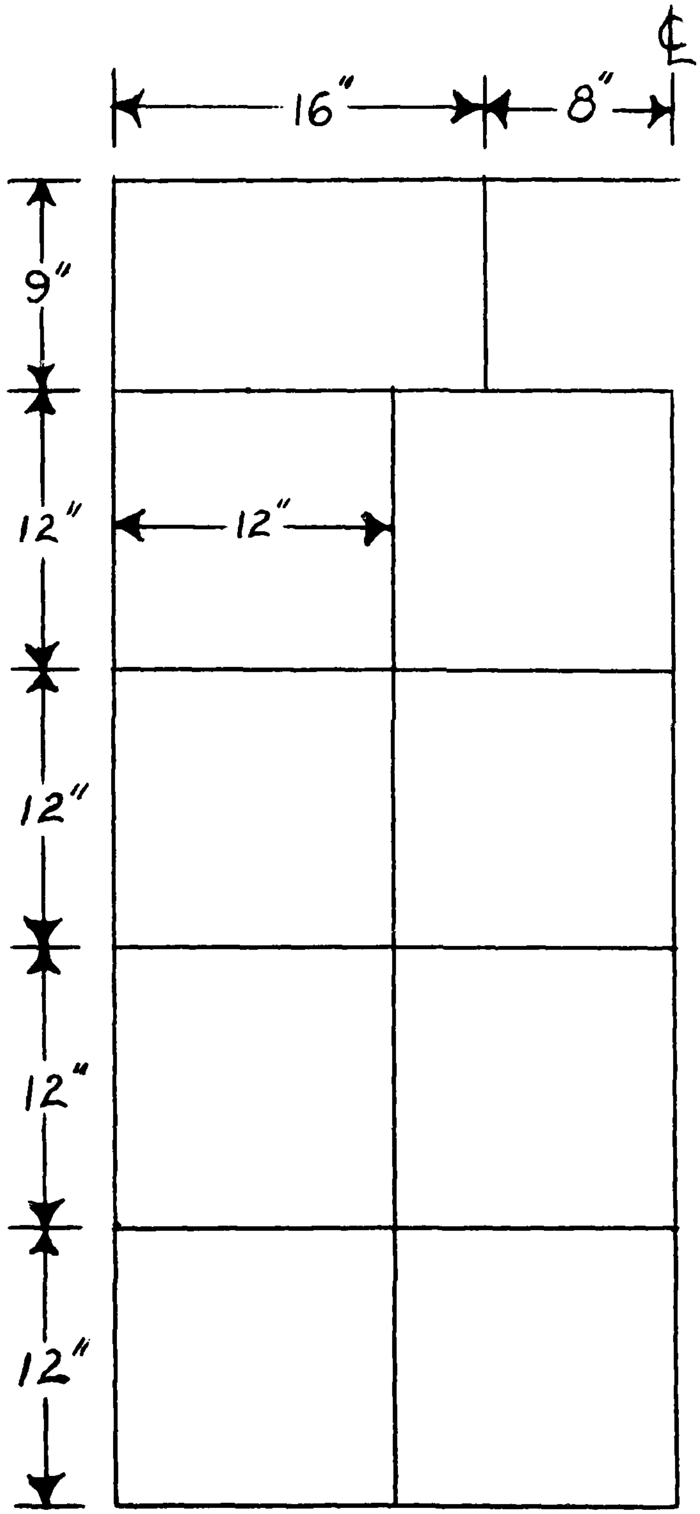
This template is used for marking a 5 inch thick "lay-up" of the material.



FOAM CUTTING TEMPLATE #2

(Half of Pattern, Flip over about ℄ for other half)

This template is used for marking a one inch thickness, or two layers of material, which ever is greater.



APPENDIX E

Taken from: First Progress Report on Field Test Program of Flotation Material dated 30 July,1981 from Underwriters Laboratories.

Buoyancy Test Method.

(a) Cushions

(1) The cushions were fastened by hand to float-buoyed hooks and the assembly (with 25 cushions attached) was lowered to a median water depth of 3 feet (0.9 meters).

(2) After being submerged for one hour, a boat-hook was used to force out residual air by pushing on the side of the cushion three times.

(3) At the end of two hours submergence, the cushions were removed from the hooks using a "plunger" and moved underwater to a weighted basket to which a scale was attached. The plunger consisted of a 6 foot pole (1.8 meters) secured to a 1 ft^2 ($0.1m^2$) board with a 25 lb. (11kg) weight attached to overcome the buoyant force of the cushion.

(4) The cushions were removed from the plunger by hand and moved into the weighted basket (still underwater) which was approximately two inches (51mm) below the water surface. After scale stabilization, the scale reading was taken.

(5) The uncorrected buoyancy (B_u) was determined to be the difference between the scale readings for the empty basket, and the basket with the cushion inserted.

(6) After B_u was determined, the cushion was removed from the water and allowed to air dry at ambient, out of direct sunlight.

(7) The procedure described in 3(a)(1) through 3(a)(6) required 5 personnel. Two persons used plungers to move the cushions, two loaded the baskets and made scale readings, and 1 was charged with recording data.

Some cushions were tested 3 times.

(8) Initially, steps 3(a)(1) through 3(a)(5) were performed at time intervals of 15 minutes, 2 hours, 4 hours, 6 hours and 24 hours on the following code numbers, considered representative of all cushions: 4, 6, 8, 9, 12, 14, 24, 30, 32, 43, 44, 48, 50 and 52. After the 24 hour reading was made, the cushions were removed from the water.

Other methods also tried.

(b) Vests

(1) Because the vests were difficult to keep under water, the following initial preparation was necessary:

-a- The left and right shoulders of all vests were tied together using light line; and,

-b- Float coats had the left and right sleeves tied together at the arm holes, also with light line.

(2) After the initial preparation, the vests and float coats were fastened by hand to float-buoyed hooks and the assembly was lowered to a median water depth of 3 feet (0.9 meters).

(3) After one hour, residual air was forced out through the bottom closing seam by pushing on each PFD 3 times with the boat hook.

(4) At the end of 2 hours, the PFD's were removed from the hooks by a submerged technician who slipped the line from the hook.

(5) The technician then moved the PFD under her body and slowly swam to the weighted basket.

(6) There, the technician slid the still submerged PFD into the weighted basket [which was approximately two inches (51mm) below the water surface] and the scale reading was taken.

(7) After determining B_u, the PFD was removed from the water and hung up to drip-and air-dry.

Taken from: First Progress Report on Field Test Program of Flotation Material dated 30 July,1981 from Underwriters Laboratories.

APPENDIX F

Shipment Dates and Code Numbers

Fletcher's Boat House, Washington, D.C., received all -1's, except 1, 4, 9, 10, 12, 16, 29, 38 and 53. Total of 45 shipped on 5/21/81.

Government Services, Inc., Washington, D.C., received all -2's, except 1, 4, 9, 10, 12, 33 and 53. Total of 47 shipped on 5/21/81.

Lenny's Boat & Motor, Avon Lake, Ohio, received all -3's, except 1, 4, 9, 10, 12, 29, 38 and 53. Total of 46 shipped on 5/21/81.

Marine Rest, Hampton Bays, New York, received all -4's, except 1, 4, 9, 10, 12, 22, 44, 50 and 53. Total of 45 shipped on 5/21/81.

Oakhaven Fish Camp, Tampa, Florida, received all -7's, except 1, 4, 9, 10, 12, 26 and 53. Total of 47 shipped 5/26/81.

Little Manatee River Outpost, Riverview, Florida, received all -8's, except 1, 4, 9, 10 and 53. Total of 49 shipped on 5/26/81.

Alafia River Outpost, Valrico, Florida, received all -9's, except 1, 4, 9, 10, 12, 43 and 53. Total of 47 shipped on 5/26/81.

Osker's Fishing Station, Hampton Bays, New York, received all -5's, except 1, 4, 9, 10, 21 and 53; and all -6's, except 1, 4, 9, 10, 12 and 16. Total of 96 shipped on 5/21/81.

Peace River Outpost, Arcadia, Florida, received all -11's, except 1, 4, 9, 10, 12 and 29; all -12's, except 1, 4, 9, 10, 12, 38 and 53; and all -13's, except 1, 4, 9, 10, 12, 16, 25, 43, 48 and 53; and numbers 16-22, 25-22 and 43-22.

Withlacoochee River Outpost, Nobleton, Florida, received all -10's, except 1, 4, 9, 10, 12, 25 and 38. Total of 47 shipped 5/26/81.

* Disney World, Lake Buena Vista, Florida, received all -14's through -20's of the following manufacturer's code numbers: 2, 3, 5, 7, 8, 11, 13-15, 17, 18, 20-24, 26-28, 31-37, 39-41, 44-47 and 49-51. Additionally, they received: 1-20, 6-(14-16), 9-(10, 14, 15), 16-(1, 6, 15-20), 19-(14-16, 18-20), 25-(15-19), 29-(15-19), 30-(14, 15, 18-20), 32-2, 38-(14-17, 19), 42-(14-18, 20), 43-(14, 16-20) and 48-(15, 19). Total of 324 shipped 6/26/81.

* Cypress Gardens, Winter Haven, Florida, received cushion number 53-18 and all -14's and -15's of the following manufacturer's code numbers: 2, 3, 5-9, 11, 13-15, 17-24, 26-28, 31-42, 44-47, 49-52 and 54. Total of 88 shipped 6/26/81.

*Some of these distributions are questionable.

APPENDIX G

Summarized Buoyancy and Buoyancy Loss Data

MFG# Code	N*	Avg.Init. Buoyancy (lb-oz)	Std.Dev. (lb)	Avg.Final Buoyancy (lb-oz)	Std.Dev. (lb)	Chg.in % Buoyancy (%)	Std.Dev. (lb)
2	10	20-03	.18	19-15	0.40	-1.14	1.56
3	9	18-15	.41	17-06	1.09	-8.48	5.48
5	10	18-04	.40	18-07	0.33	+1.28	2.68
6	10	18-15	.40	19-02	1.16	+1.00	4.95
7	9	19-02	.42	18-11	1.75	-2.12	8.40
8	8	21-10	.48	19-05	1.74	-10.78	8.84
11	10	20-02	.26	20-00	0.59	-0.65	2.48
12	8	16-14	.69	13-00	1.76	-22.80	11.89
13	9	19-12	.60	19-13	0.39	+0.37	2.22
14	10	19-08	.29	18-12	1.38	-3.94	7.59
15	9	20-02	.56	19-13	0.38	-1.49	2.13
16	8	18-13	.42	15-11	2.43	-16.62	13.10
17	10	18-03	.23	17-15	0.59	-1.28	3.04
18	10	19-05	.40	18-08	1.20	-4.28	5.64
19	10	19-02	.23	18-01	1.17	-5.48	5.86
20	9	20-02	.41	20-01	0.42	-0.47	1.03
21	9	18-15	.79	13-08	2.72	-29.12	11.80
22	9	18-04	.46	17-12	0.48	-2.83	1.08
23	8	20-12	.73	19-05	2.15	-6.90	8.46
24	10	23-01	.50	21-13	1.98	-5.19	8.80
25	8	17-15	.44	16-10	0.33	-7.08	1.97
26	10	21-01	.14	20-10	0.22	-2.24	0.95
27	9	19-07	.52	19-08	0.68	+0.42	2.73
28	9	21-04	.18	20-14	0.52	-1.75	2.03
29	7	18-06	.46	12-07	4.04	-32.51	21.54
30	9	18-01	.57	9-10	3.22	-46.33	18.98
31	10	20-08	.51	15-00	2.60	-32.36	13.58
32	9	21-05	.28	20-03	3.01	-0.05	3.65
33	7	18-08	.60	16-01	2.06	-14.72	7.27
34	10	20-13	.11	18-05	0.74	-12.05	3.56
35	9	19-08	.37	18-10	1.52	-4.49	6.45
36	10	19-06	.29	19-07	0.31	+0.29	1.30
37	10	19-14	.51	14-00	3.74	-27.71	14.64
38	7	17-14	.17	13-07	2.72	-24.85	15.73
39	10	21-06	.50	19-14	1.18	-7.01	3.78
40	10	19-11	.43	19-03	0.47	-2.43	2.86
41	9	18-14	.26	16-01	2.09	-14.74	11.19
42	10	19-10	.43	19-15	0.38	+1.50	3.36
43	8	19-11	1.40	19-08	1.18	-0.89	4.38

MFG# Code	N*	Avg.Init. Buoyancy (lb-oz)	Std.Dev. (lb)	Avg.Final Buoyancy (lb-oz)	Std.Dev. (lb)	Chg.in % Buoyancy (%)	Std.Dev. (lb)
44	10	18-06	.44	13-03	3.24	-27.92	17.86
45	10	19-10	.32	17-07	0.78	-11.19	3.65
46	8	19-01	.22	18-10	0.48	-2.27	1.90
47	10	18-14	.13	19-11	0.48	+4.28	2.34
48	9	18-02	.36	17-08	1.18	-3.33	5.95
49	10	20-05	.37	19-14	0.78	-2.30	3.27
50	10	18-07	.40	13-01	4.64	-32.75	17.96
51	10	18-15	.26	18-00	0.56	-5.00	3.31
52	10	18-14	.30	14-10	2.58	-22.40	13.68
53	3	17-11	.13	9-14	1.12	-43.90	6.18
54	10	19-08	.11	19-00	0.24	-2.58	1.34

*N=Number of Sample Cushions